



MEMORANDUM

To: EPA
Copy To: File D0001
From: J. Lambert, J. Brunelle, T. DeLong
Subject: Olin: Cleanup Level for Ammonia in Surface Water
Date: 03/11/2021

The U.S. Environmental Protection Agency (EPA) received a comment on the Proposed Plan (EPA, 2020) for the Olin Chemical Superfund Site (the Site) suggesting that the preliminary remediation goal (PRG) developed for the Operable Unit (OU)1/OU2 Feasibility Study (FS) (Olin 2021) for ammonia in surface water was too high (insufficiently protective). This Technical Memorandum (Memo) documents the results of EPA's re-evaluation of the ammonia criterion.

1.0 PRG DEVELOPMENT

The default value for the Aquatic Life Ambient Water Quality Criterion (AWQC) for ammonia in surface water is 7.1 mg/l. This is based on a standard pH of 7, a standard temperature of 20 degrees Celsius, and a selected Criterion Continuous Concentration (CCC) that reflects an absence of early life stage fish and mussels (EPA, 2013). This CCC was selected because the habitats in the East Ditch Stream and the South Ditch Stream are not suitable for mussels or fish.

In 2019, Wood provided a technical memorandum (Wood, 2019) that recommended a site-specific AWQC for ammonia. Wood developed the ammonia PRG in accordance with Appendix N, Table N.9 of the AWQC guidance (EPA, 2013) using site-specific pH and temperature representative of Site spring season surface water and a CCC that reflects an absence of early life stage fish and mussels. The site-specific criteria for temperature and pH for both the East Ditch Stream and the South Ditch Stream were based on the mean value for samples collected in March and April from 2013 to 2019. These resulted in the following CCC values:

- East Ditch Stream: temperature 9°C, pH 7.1 = 14 milligrams per liter (mg/L) CCC.
- South Ditch Stream: temperature 7°C, pH 6.5 = 19 mg/L CCC



During FS development in 2020, Wood provided a summary memorandum documenting the basis for PRGs for soil, sediment, and surface water (Wood, 2020). This included the CCC values provided above and noted that EPA had determined that a PRG of 15 mg/L was appropriate.

In response to the Proposed Plan comment, Wood provided a supplemental technical memorandum (Wood, 2021) that evaluated an expanded surface water set and reviewed anomalous surface water pH data. Based on the revised surface water data set, Wood adjusted the pH to 6.58 for the East Ditch Stream and 6.12 for the South Ditch Stream. This data set used an average pH for all four quarters. The pH value did not vary significantly seasonally, with average quarterly values ranging from 6.40 to 6.63 for the East Ditch Stream and 5.94 to 6.18 for the South Ditch Stream. Wood concluded that the PRG of 15 mg/L from the Proposed Plan was still appropriate.

2.0 FINAL PERFORMANCE STANDARDS

Based on public comment, in 2021 EPA revisited how the ammonia surface water PRG was established. EPA adjusted the ammonia surface water PRG presented in the Proposed Plan because the spring temperatures used were not sufficiently representative.

The PRG presented in the Proposed Plan is based on spring temperatures from March and April. While EPA agrees that generally spring temperatures should be used as the basis for developing criteria, it is more appropriate to use a value based on the in-stream temperature in late spring (between May and June instead of late March and early April), as late spring temperatures reflect a period when aquatic receptors will be more active, and epi-benthic organisms that are exposed to ambient water will be present in the water column. Also, the Baseline Ecological Risk Assessment (BERA) (AMEC, 2015) assumed that the Marsh Wren and Green Heron may forage on-site. Adjusting to late spring temperatures would account for the time when both species would be present and breeding in New England.

Nobis used the 2nd quarter temperature data from Table 1 from Wood, 2021 (Attachment A) to develop representative temperatures, using the 95% upper confidence limit (UCL) for all results from the South Ditch Stream and East Ditch Stream. EPA's ProUCL software (version 5.1) was used to determine the appropriate 95% UCL from each data set. ProUCL output summaries are included in Attachment B. These resulted in a temperature of 18.11°C for the East Ditch Stream (Student's-t UCL) and 14.65°C for the South Ditch Stream (student's-t UCL).



Nobis used the pH values for each stream as calculated in Wood, 2021 (average results from all four quarters, excluding anomalies) and the temperature data based on the 2nd quarter 95% UCL to compare against the suggested criteria in EPA, 2013, attachment N.9 (Attachment C). Based on this comparison, the following concentrations were developed:

- East Ditch Stream: Temperature = 18°C, pH = 6.6: 9.0 mg/L
- South Ditch Stream: Temperature = 15°C, pH = 6.1: 11 mg/L

Based on these values, the final performance standard for ammonia in surface water was set at 9 mg/L.

3.0 REFERENCES

AMEC Environment & Infrastructure, Inc. Final Baseline Ecological Risk Assessment, Operable Unit 1 & Operable Unit 2, Olin Chemical Superfund Site, 51 Eames Street, Wilmington, MA. July 24.

EPA, 2013. Aquatic Ambient Water Quality Criteria for Ammonia – Freshwater, 2013. EPA 822-R-18-002, April.

EPA, 2020. Proposed Plan, Olin Chemical Superfund Site, Wilmington, MA. August.

Olin, 2020. Operable Unit 1 & Operable Unit 2 Feasibility Study (Volume 1), Olin Chemical Superfund Site, 51 Eames Street, Wilmington, MA. July 31.

Wood, 2019. Technical Memorandum RE: Site-Specific AWQC for Ammonia – Olin Chemical Superfund Site. November 25.

Wood, 2020. Technical Memorandum RE: Documentation of Preliminary Remediation Goals (PRGs) for Soils, Sediments, and Surface Water at the Olin Chemical Superfund Site. May 15.

Table 1
Summary of Temperature and pH - East and South Ditches Surface Water
Slurry Wall/Cap Monitoring Program
Olin Chemical Superfund Site
Wilmington, Massachusetts

Quarters	Sample Date	Temperature (° C)										pH (standard units)							
		East Ditch			South Ditch							East Ditch			South Ditch				
		ISCO-3	ED-SW10*	ED-SW11*	ISCO-1	ISCO-2	PZ-16RRR	PZ-17RRR	PZ-18R	SD-17	ISCO-3	ED-SW10*	ED-SW11*	ISCO-1	ISCO-2	PZ-16RRR	PZ-17RRR	PZ-18R	SD-17
Quarter 1	3/6/2008	8.65	-	-	4.07	5.55	3.49	3.41	4.34	5.02	6.84	-	-	5.74	5.56	5.59	5.54	5.83	5.57
	2/24/2009	1.15	-	-	0.94	0.04	0.17	0.85	0.96	0.99	6.8	-	-	5.7	5.54	5.51	5.32	5.9	5.43
	2/18/2010	3.27	-	-	-0.50	0.19	2.04	2.93	-0.21	3.16	6.81	-	-	5.96	6.24	6.29	6.33	5.99	6.29
	3/22/2011	6.94	-	-	5	4.33	4.61	5.19	5.13	5.45	6.18	-	-	5.70	4.66	5.53	5.89	5.68	6.02
	2/23/2012	16.22	-	-	9	14.39	13.23	12.72	11.75	13	5.39	-	-	5.63	5.63	5.57	5.21	5.6	5.51
	3/21/2013	2.40	-	-	3.14	1.48	1.89	2.47	3.28	2.52	6.90	-	-	6.26	6.42	5.88	6.12	6.13	6.20
	4/2/2014	8.53	-	-	7.17	6.14	6.20	6.29	7.23	6.70	6.89	-	-	6.01	6.30	6.00	5.96	6.04	5.95
	4/14/2015	11.41	-	-	11.65	11.02	11.26	10.85	11.68	10.84	6.56	-	-	5.72	6.18	5.93	5.91	5.80	5.82
	3/22/2016	-	-	-	5.60	4.07	4.16	4.96	5.77	4.96	-	-	-	5.95	5.97	6.61	7.30	6.03	7.29
	3/30/2017	9.33	-	-	5.90	5.99	5.47	5.51	5.21	5.80	6.67	-	-	5.85	6.27	6.71	6.43	5.73	6.44
	4/12/2018	9.19	-	-	8.52	7.17	8.85	7.54	8.87	7.47	8.93	-	-	7.03	8.88	8.78	8.56	7.48	8.41
	4/2/2019	14.34	-	-	8.57	9.07	10.41	9.85	9.10	10.13	6.82	-	-	6.28	6.24	6.07	5.95	5.94	5.90
3/16/2020	4.79	11.09	12.07	8.77	1.55	2.99	5.19	5.69	5.46	6.8	6.72	6.86	5.88	6.29	6.14	5.99	6.34	5.98	
Quarter 2	5/22/2008	12.3	-	-	13.6	12.4	12.9	13.4	13.3	13.6	5.56	-	-	5.84	5.18	5.72	5.4	5.4	5.94
	5/12/2009	16.75	-	-	12.84	17.26	15.2	14.88	12.72	14.86	7.01	-	-	5.88	6.87	6.59	6.32	6.04	6.33
	6/9/2010	17.22	-	-	15.4	14.4	15.11	16.45	16.31	16.67	6.96	-	-	6.33	6.57	6.27	6.65	6.46	6.48
	5/16/2011	11.27	-	-	11	11.14	11.15	10.87	10.67	10.68	6.84	-	-	12	6.3	6.18	6.53	6.97	6.87
	6/7/2012	19.66	-	-	18	18.67	19.15	18.84	18.09	18.07	5.65	-	-	5.66	5.88	5.7	5.5	5.68	5.37
	5/13/2013	10.98	-	-	10.46	10.87	11.09	11.21	10.71	11.22	6.49	-	-	5.92	6.25	5.79	5.83	5.89	5.41
	5/29/2014	20.74	-	-	12.90	13.72	12.92	12.85	13.43	12.88	6.64	-	-	6.35	6.68	6.70	6.63	6.39	6.56
	5/27/2015	21.53	-	-	19.74	20.93	22.96	12.14	20.09	17.46	6.59	-	-	5.92	6.54	6.65	6.02	5.94	6.01
	5/25/2016	17.48	-	-	15.25	15.23	14.34	14.65	15.20	14.73	7.83	-	-	6.01	6.10	6.31	6.35	6.05	6.45
	5/10/2017	10.38	-	-	9.95	9.78	9.91	10.11	9.94	10.05	6.83	-	-	7.10	6.92	6.86	7.03	7.21	6.99
	5/22/2018	20.39	-	-	14.51	18.12	17.07	17.30	14.99	15.41	5.81	-	-	9.04	7.09	7.85	9.03	9.01	8.83
5/29/2019	12.32	-	-	11.72	11.34	11.36	11.53	11.59	11.56	6.59	-	-	6.02	6.29	6.21	6.08	5.92	6.04	

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Olin Chemical Superfund Site
Wilmington, Massachusetts

Quarters	Sample Date	Temperature (° C)									pH (standard units)									
		East Ditch			South Ditch						East Ditch			South Ditch						
		ISCO-3	ED-SW10*	ED-SW11*	ISCO-1	ISCO-2	PZ-16RRR	PZ-17RRR	PZ-18R	SD-17	ISCO-3	ED-SW10*	ED-SW11*	ISCO-1	ISCO-2	PZ-16RRR	PZ-17RRR	PZ-18R	SD-17	
Quarter 3	8/22/2007	14.2	-	-	17.6	13.5	10.48	16	17.4	17.8	5.56	-	-	6.72	6	6.67	5.92	6.47	6.29	
	8/27/2008	15.14	-	-	17.99	15.07	16.98	17.93	17.21	18.05	5.79	-	-	6.56	6.36	6.63	6.59	6.94	6.68	
	8/12/2009	18.33	-	-	20.28	18.68	18.4	18.14	20.13	18.07	6.87	-	-	6.17	6.63	5.34	5.78	6.17	5.21	
	9/1/2010	29.35	-	-	25	25.11	26.94	22.3	25.3	19.37	6.38	-	-	3.62	5.46	6.4	6.56	4.24	5.59	
	8/23/2011	22.08	-	-	25	21.37	21.43	21.77	23.19	22.02	6.18	-	-	6.00	6.31	5.75	5.65	5.78	5.25	
	8/23/2012	32.84	-	-	23	21.55	21.82	22.03	22.88	21.14	6.02	-	-	6.22	6.48	6.33	5.38	6.14	5.81	
	8/22/2013	18.46	-	-	20.78	19.68	19.19	17.51	20.56	17.03	6.36	-	-	6.21	6.52	6.24	5.43	5.85	5.11	
	8/26/2014	22.82	-	-	19.45	21.70	28.18	18.37	19.37	18.13	6.66	-	-	6.11	6.46	6.39	5.77	6.22	5.36	
	8/19/2015	24.63	-	-	23.24	21.73	22.20	19.56	23.40	18.65	6.83	-	-	6.40	6.51	6.57	5.70	6.40	4.98	
	2016 ¹	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8/3/2017	20.21	-	-	20.01	22.07	21.77	19.82	20.70	19.32	7.57	-	-	7.47	8.27	8.03	7.66	7.83	7.37	
	2018 ¹	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	8/21/2019	22.04	-	-	20.97	20.48	20.06	18.59	21.34	17.86	7.01	-	-	6.13	6.47	6.42	6.04	6.17	5.82	
Quarter 4	11/12/2007	6.3	-	-	5.49	4.88	6.65	7.11	5.81	7.42	6.58	-	-	5.93	6.91	6.04	5.95	6.22	5.56	
	11/18/2008	4.7	-	-	5.3	7.4	5.3	7	4.1	6.8	6.01	-	-	5.73	6.2	5.24	4.92	4.92	5.08	
	11/12/2009	7.01	-	-	7.31	6.15	8.43	10.34	7.23	10.22	6.64	-	-	6.07	6.18	6.01	6.12	6.01	5.98	
	11/15/2010	13.73	-	-	11.83	12.63	12.55	12.68	11.57	12.44	4.02	-	-	4	4.22	4.25	4.24	4.22	4.22	
	11/8/2011	12.43	-	-	11	10.19	11.37	11.43	9.59	11.38	6.74	-	-	6	6.33	6.49	6.33	6	6.29	
	11/16/2012	5.56	-	-	5	4.26	5.62	6.33	5.33	7.39	6.43	-	-	6	5.99	5.83	5.56	5.77	5.57	
	11/21/2013	-0.11	-	-	4.26	2.49	-0.07	5.32	3.79	6.13	6.93	-	-	6.38	6.49	6.31	5.91	6.21	6.33	
	11/6/2014	9.83	-	-	8.52	8.73	8.72	8.96	8.64	8.96	6.19	-	-	5.97	6.22	5.97	5.84	6.02	5.79	
	11/3/2015	12.04	-	-	9.36	11.64	13.25	12.07	11.96	9.52	6.86	-	-	6.40	6.33	6.16	5.98	5.96	6.30	
	11/17/2016	11.23	-	-	10.79	10.90	10.81	10.89	10.68	10.91	6.97	-	-	6.10	8.44	7.68	7.89	6.54	7.64	
	11/15/2017	8.58	-	-	5.17	6.51	7.77	8.49	5.10	8.45	7.13	-	-	7.07	7.01	7.48	7.76	7.18	7.8	
	12/4/2018	NS	-	-	6.03	6.11	5.70	6.20	5.98	6.19	NS	-	-	6.59	5.63	5.76	6.12	6.55	6.20	
12/16/2019	5.47	-	-	4.67	2.65	3.74	4.30	4.66	4.40	6.6	-	-	6.06	6.00	5.98	5.89	5.87	5.88		

Yellow shading indicates pH values that appear to be higher than typical pH values from 2007 to 2019 (potential outliers)
Green shading indicates pH values that appear to be lower than typical pH values from 2007 to 2019 (potential outliers)

Prepared by: CF 11/13/2020
Checked by: MJM 12/11/2020

Notes:

- = no sample collected
- NS = Not able to collect sample
- * - EPA added East Ditch Surface Water Locations
- 1. In 2016 and 2018, the surface water sample locations were dry, no samples collected

UCL Statistics for Uncensored Full Data Sets			
EAST DITCH STREAM - ALL QUARTER 2 (MID-MAY TO JUNE) TEMPERATURES			
User Selected Options			
Date/Time of Computation	ProUCL 5.13/10/2021 11:49:24 AM		
From File	WorkSheet.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
C0			
General Statistics			
Total Number of Observations	12	Number of Distinct Observations	12
		Number of Missing Observations	1
Minimum	10.38	Mean	15.92
Maximum	21.53	Median	16.99
SD	4.224	Std. Error of Mean	1.219
Coefficient of Variation	0.265	Skewness	-0.0688
Normal GOF Test			
Shapiro Wilk Test Statistic	0.881	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.22	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	18.11	95% Adjusted-CLT UCL (Chen-1995)	17.9
		95% Modified-t UCL (Johnson-1978)	18.1
Gamma GOF Test			
A-D Test Statistic	0.689	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.731	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.221	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.245	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	14.8	k star (bias corrected MLE)	11.15
Theta hat (MLE)	1.076	Theta star (bias corrected MLE)	1.427
nu hat (MLE)	355.1	nu star (bias corrected)	267.7
MLE Mean (bias corrected)	15.92	MLE Sd (bias corrected)	4.767
		Approximate Chi Square Value (0.05)	230.8
Adjusted Level of Significance	0.029	Adjusted Chi Square Value	225.6
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	18.46	95% Adjusted Gamma UCL (use when n<50)	18.89
Lognormal GOF Test			

Shapiro Wilk Test Statistic	0.873	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.859	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.205	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.243	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.34	Mean of logged Data	2.733
Maximum of Logged Data	3.069	SD of logged Data	0.277
Assuming Lognormal Distribution			
95% H-UCL	18.74	90% Chebyshev (MVUE) UCL	19.78
95% Chebyshev (MVUE) UCL	21.52	97.5% Chebyshev (MVUE) UCL	23.94
99% Chebyshev (MVUE) UCL	28.7		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	17.92	95% Jackknife UCL	18.11
95% Standard Bootstrap UCL	17.8	95% Bootstrap-t UCL	18.16
95% Hall's Bootstrap UCL	17.7	95% Percentile Bootstrap UCL	17.75
95% BCA Bootstrap UCL	17.92		
90% Chebyshev(Mean, Sd) UCL	19.58	95% Chebyshev(Mean, Sd) UCL	21.23
97.5% Chebyshev(Mean, Sd) UCL	23.53	99% Chebyshev(Mean, Sd) UCL	28.05
Suggested UCL to Use			
95% Student's-t UCL	18.11		
<p>Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. Recommendations are based upon data size, data distribution, and skewness. These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006). However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.</p>			
<p>Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.</p>			

UCL Statistics for Uncensored Full Data Sets			
SOUTH DITCH STREAM - ALL QUARTER 2 (MID-MAY TO JUNE) TEMPERATURES			
User Selected Options			
Date/Time of Computation	ProUCL 5.13/10/2021 11:36:36 AM		
From File	WorkSheet.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		
C0			
General Statistics			
Total Number of Observations	72	Number of Distinct Observations	68
		Number of Missing Observations	1
Minimum	9.78	Mean	14.04
Maximum	22.96	Median	13.52
SD	3.093	Std. Error of Mean	0.364
Coefficient of Variation	0.22	Skewness	0.658
Normal GOF Test			
Shapiro Wilk Test Statistic	0.934	Shapiro Wilk GOF Test	
5% Shapiro Wilk P Value	0.00112	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.107	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	14.65	95% Adjusted-CLT UCL (Chen-1995)	14.67
		95% Modified-t UCL (Johnson-1978)	14.65
Gamma GOF Test			
A-D Test Statistic	0.831	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.749	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.107	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.105	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	21.95	k star (bias corrected MLE)	21.05
Theta hat (MLE)	0.64	Theta star (bias corrected MLE)	0.667
nu hat (MLE)	3161	nu star (bias corrected)	3031
MLE Mean (bias corrected)	14.04	MLE Sd (bias corrected)	3.06
		Approximate Chi Square Value (0.05)	2904
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	2901
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	14.65	95% Adjusted Gamma UCL (use when n<50)	14.67
Lognormal GOF Test			

Shapiro Wilk Test Statistic	0.951	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk P Value	0.017	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.104	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.104	Data appear Lognormal at 5% Significance Level	
Data appear Approximate Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.28	Mean of logged Data	2.619
Maximum of Logged Data	3.134	SD of logged Data	0.214
Assuming Lognormal Distribution			
95% H-UCL	14.66	90% Chebyshev (MVUE) UCL	15.11
95% Chebyshev (MVUE) UCL	15.59	97.5% Chebyshev (MVUE) UCL	16.27
99% Chebyshev (MVUE) UCL	17.59		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	14.64	95% Jackknife UCL	14.65
95% Standard Bootstrap UCL	14.64	95% Bootstrap-t UCL	14.7
95% Hall's Bootstrap UCL	14.67	95% Percentile Bootstrap UCL	14.68
95% BCA Bootstrap UCL	14.64		
90% Chebyshev(Mean, Sd) UCL	15.13	95% Chebyshev(Mean, Sd) UCL	15.63
97.5% Chebyshev(Mean, Sd) UCL	16.32	99% Chebyshev(Mean, Sd) UCL	17.67
Suggested UCL to Use			
95% Student's-t UCL	14.65	or 95% Modified-t UCL	14.65
or 95% H-UCL	14.66		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
ProUCL computes and outputs H-statistic based UCLs for historical reasons only.			
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.			
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.			
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.			

Table N.9. Temperature and pH-Dependent Values of the CCC (Chronic Criterion Magnitude) – Mussels Absent and Early Life Stage (ELS) Protection not Necessary.

pH	Temperature (°C)																													
	0-7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30						
6.5	19	17	16	15	14	13	13	12	11	10	9.7	9.1	8.5	8.0	7.5	7.0	6.6	6.2	5.8	5.4	5.1	4.8	4.5	4.2						
6.6	18	17	16	15	14	13	12	12	11	10	9.6	9.0	8.4	7.9	7.4	6.9	6.5	6.1	5.7	5.4	5.0	4.7	4.4	4.1						
6.7	18	17	16	15	14	13	12	11	11	10	9.4	8.8	8.3	7.7	7.3	6.8	6.4	6.0	5.6	5.3	4.9	4.6	4.3	4.1						
6.8	17	16	15	14	14	13	12	11	10	9.8	9.2	8.6	8.1	7.6	7.1	6.7	6.2	5.8	5.5	5.1	4.8	4.5	4.2	4.0						
6.9	17	16	15	14	13	12	12	11	10	9.5	8.9	8.4	7.8	7.4	6.9	6.5	6.1	5.7	5.3	5.0	4.7	4.4	4.1	3.9						
7.0	16	15	14	14	13	12	11	10	9.8	9.2	8.6	8.1	7.6	<u>7.1</u>	6.7	6.2	5.9	5.5	5.1	4.8	4.5	4.2	4.0	3.7						
7.1	16	15	14	13	12	11	11	10	9.4	8.8	8.3	7.7	7.3	6.8	6.4	6.0	5.6	5.3	4.9	4.6	4.3	4.1	3.8	3.6						
7.2	15	14	13	12	12	11	10	9.5	9.0	8.4	7.9	7.4	6.9	6.5	6.1	5.7	5.3	5.0	4.7	4.4	4.1	3.9	3.6	3.4						
7.3	14	13	12	12	11	10	9.6	9.0	8.4	7.9	7.4	6.9	6.5	6.1	5.7	5.4	5.0	4.7	4.4	4.1	3.9	3.6	3.4	3.2						
7.4	13	12	12	11	10	9.5	9.0	8.4	7.9	7.4	6.9	6.5	6.1	5.7	5.3	5.0	4.7	4.4	4.1	3.9	3.6	3.4	3.2	3.0						
7.5	12	11	11	10	9.4	8.8	8.2	7.7	7.2	6.8	6.4	6.0	5.6	5.2	4.9	4.6	4.3	4.1	3.8	3.6	3.3	3.1	2.9	2.8						
7.6	11	10	10	9.1	8.5	8.0	7.5	7.0	6.6	6.2	5.8	5.4	5.1	4.8	4.5	4.2	3.9	3.7	3.5	3.2	3.0	2.9	2.7	2.5						
7.7	9.9	9.3	8.7	8.1	7.7	7.2	6.8	6.3	5.9	5.6	5.2	4.9	4.6	4.3	4.0	3.8	3.5	3.3	3.1	2.9	2.7	2.6	2.4	2.3						
7.8	8.8	8.3	7.8	7.3	6.8	6.4	6.0	5.6	5.3	5.0	4.6	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0						
7.9	7.8	7.3	6.8	6.4	6.0	5.6	5.3	5.0	4.6	4.4	4.1	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8						
8.0	6.8	6.3	6.0	5.6	5.2	4.9	4.6	4.3	4.0	3.8	3.6	3.3	3.1	2.9	2.7	2.6	2.4	2.3	2.1	2.0	1.9	1.7	1.6	1.5						
8.1	5.8	5.5	5.1	4.8	4.5	4.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3						
8.2	5.0	4.7	4.4	4.1	3.9	3.6	3.4	3.2	3.0	2.8	2.6	2.5	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1						
8.3	4.2	4.0	3.7	3.5	3.3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.96						
8.4	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	0.99	0.92	0.87	0.81						
8.5	3.0	2.8	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	0.95	0.89	0.83	0.78	0.73	0.69						
8.6	2.6	2.4	2.2	2.1	2.0	1.9	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.97	0.91	0.85	0.80	0.75	0.70	0.66	0.62	0.58						
8.7	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.93	0.88	0.82	0.77	0.72	0.68	0.63	0.60	0.56	0.52	0.49						
8.8	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.1	1.0	0.96	0.90	0.85	0.79	0.74	0.70	0.65	0.61	0.58	0.54	0.51	0.47	0.44	0.42						
8.9	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	0.94	0.88	0.82	0.77	0.72	0.68	0.64	0.60	0.56	0.52	0.49	0.46	0.43	0.40	0.38	0.36						
9.0	1.4	1.3	1.2	1.1	1.0	0.98	0.92	0.86	0.81	0.76	0.71	0.66	0.62	0.58	0.55	0.51	0.48	0.45	0.42	0.40	0.37	0.35	0.33	0.31						